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STUDY OF LUNAR REFLECTIVE COMPONENTS OF SOLAR RADIO EMISSION

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by

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Introduction

The primary purposes of this project are to develop and test a high speed digital correlator and to investigate application of such a correlator to detection of radio frequency solar energy reflected from the lunar surface.

By performing a crosscorrelation of the signal received by a radio telescope pointed toward the moon with that received by another radio telescope pointed toward the sun, a direct measurement of reflecting properties of the lunar surface can be obtained. The amount of delay between the direct and reflected signals is dependent on the aspect angle between the sun and moon and varies from 1.27 seconds for an angle of 90° (half moon) to 95 microseconds for an angle of 179° (almost new moon). The correlation function will have a significant value over the interval of delay required for the incident solar radiation to traverse the moon. These correlation times vary from 8.2 milliseconds for the half moon to 101 microseconds for an almost new moon.

The autocorrelation function of the lunar radiation has the same correlation time (i.e. a few hundred to a few thousand microseconds) as the crosscorrelation function of the solar and lunar signals. The autocorrelation function will have its maximum value at the origin and therefore the large delays required for obtaining the crosscorrelation function will not be required. As is to be expected, the signal-to-noise ratio for autocorrelation is much poorer than for crosscorrelation.

The effective bandwidth of the correlator must be sufficient to permit resolution of the fine structure of the correlation function which corresponds to fine spatial resolution on the lunar surface. As dictated by the state of the art, a preliminary design goal of 100 Mc.has been set for the bandwidth of the correlator although very good performance can be obtained for most phases of the moon with one or two orders of magnitude less bandwidth.

The correlation functions of interest in this application are the correlation functions of the raw RF signals. If these signals could be correlated directly, a relatively smooth correlation function extending out to the maximum correlation time would be obtained. However, when the signals are passed through a bandpass filter such as a radio receiver, the correlation function becomes oscillatory with a frequency equal to the center frequency of the filter. The envelope of this oscillating correlation function is proportional to the desired correlation function. The correlator for this application must, therefore, be one which measures the envelope of the correlation function of the receiver output rather than the correlation function itself.

Present Status

A correlation technique has been devised which measures the envelope of the correlation function of gaussian signals. This technique is suitable for determining both autocorrelation and crosscorrelation functions. Since the sun's blackbody radiation is an RF signal with an amplitude having a gaussian probability distribution, this technique is directly applicable to the problem.

A preliminary mathematical analysis has been made establishing the validity of the method and providing estimates of accuracy and smoothing times for various input signal-to-noise ratios.

The correlator proper utilizes digital circuitry operating at a 1 Mc. rate. The large effective bandwidth of the correlator is obtained by sampling the input signal with a narrow pulse (less than 10 ns. wide) occurring at a 1 Mc. rate. The repetition frequency of 1 Mc. was selected so as to permit storage and delay of the digital signals by a commercially available large capacity device such as a tape unit or a magneto-strictive delay line.

Experimental work is underway on the input stages of the correlator where limiting and sampling of 100 Mc. video signals occur and where most of the engineering problems lie. The configuration of the remainder of the correlator has been finalized and components are being procured.

An investigation is underway to devise suitable test and calibration procedures for the correlator. It is desired to synthesize a video signal having a large bandwidth and a relatively long correlation time with a non-oscillatory correlation function. It can be shown that such signals are physically realizable but so far no practical way of generating them has been found.

An analytical study is being carried out to determine the characteristics of the correlation functions of signals reflected by the moon. This study is based upon determination of the forward scattering impulse response of the moon for electro-magnetic waves under various assumptions regarding the surface reflectively, angle of incidence of radiation and other parameters. A computer program is being prepared which will incorporate the various astronomical parameters as well as providing flexibility for handling various laws of scattering and various characteristics of the antennas receiving the solar and lunar signals. At the present time it appears that the resolution obtainable on the lunar surface will be limited in one dimension by the beamwidth of the receiving antenna and in the other by the bandwidth of the correlator. A general defocussing effect will also occur due to the finite size of the source, i.e. the sun, however, this can be minimized by using a narrow beam antenna directed toward the sun thus restricting the region of the sun providing the reference signal for crosscorrelation.

Future Work

By early fall it is expected that the first experimental model of the correlator will be completed and under test in the laboratory. This model will have a relatively short time delay capacity but should be adequate for experimental measurement of portions of the autocorrelation function of lunar reflected solar energy. It is planned to test the correlator at the University of Michigan Radio Astronomy Facility around the first of the year.

Computation will be made of the expected shape and absolute magnitude of the correlation functions of lunar reflected solar energy based on various assumptions regarding the lunar scattering mechanism. These computations will be used as a basis for more detailed specifications of required correlator performance and to aid in the analysis of experimental data obtained by actual measurement.

Studies of testing and simulation will be continued and a suitable calibration procedure will be developed for the correlator.